Nuclear data needs for Gen IV

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Nuclear Data Issues – Minor Actinides (MIT Study: P. Hejzlar)

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- Neutronic analyses for advanced systems (ADS and Gen IV) rely on nuclear data libraries
- Data (fission, capture) discrepancies exist for hard spectrum systems: order of tens of percent

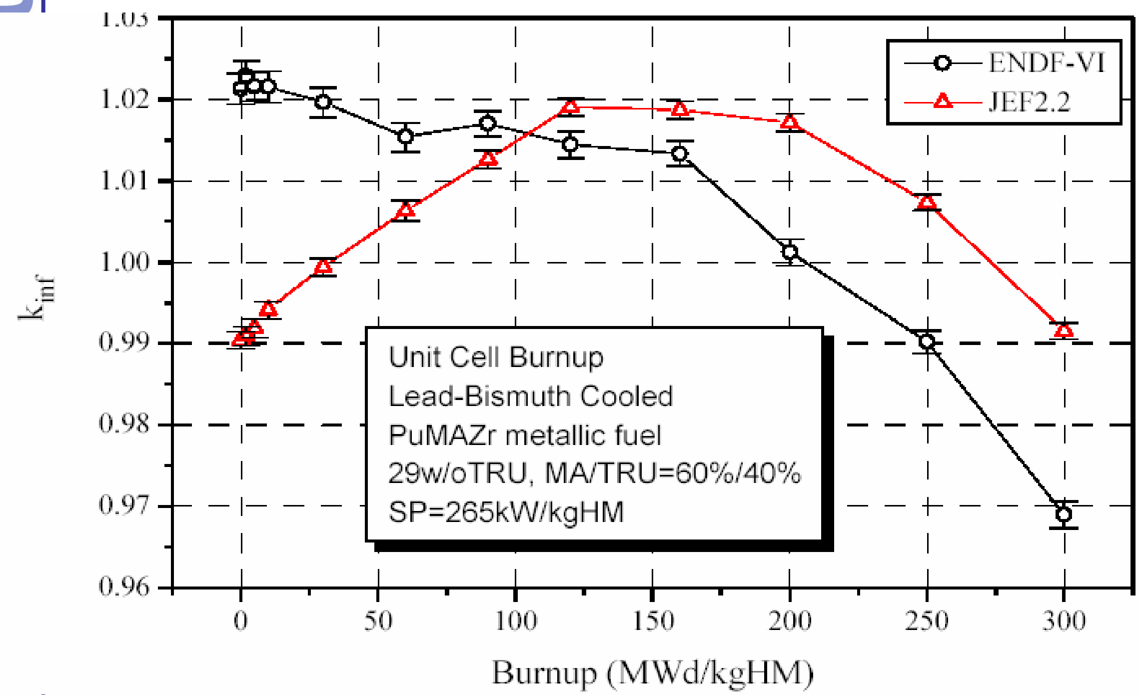


TABLE I. Spectrum-average One-Group Cross Sections*.

	JEF2.2		ENDF-VI	
Actinide	σ_f(b)	σ_c(b)	σ_f(b)	σ_c (b)
Np237	0.307	1.190	0.304	1.220
Pu238	1.080	0.412	1.070	0.579
Pu239	1.670	0.357	1.650	0.342
Pu240	0.360	0.414	0.356	0.392
Pu241	2.190	0.466	2.190	0.311
Pu242	0.250	0.357	0.245	0.343
Am241	0.228	1.590	0.232	1.330
Am242m	2.750	0.430	3.330	0.270
Am243	0.174	1.330	0.181	1.140
Cm242	0.581	0.359	0.123	0.208
Cm243	2.880	0.149	2.230	0.173
Cm244	0.408	0.446	0.400	0.687
Cm245	2.310	0.247	2.010	0.261

*Maximum statistical error in σ of $\pm$0.006

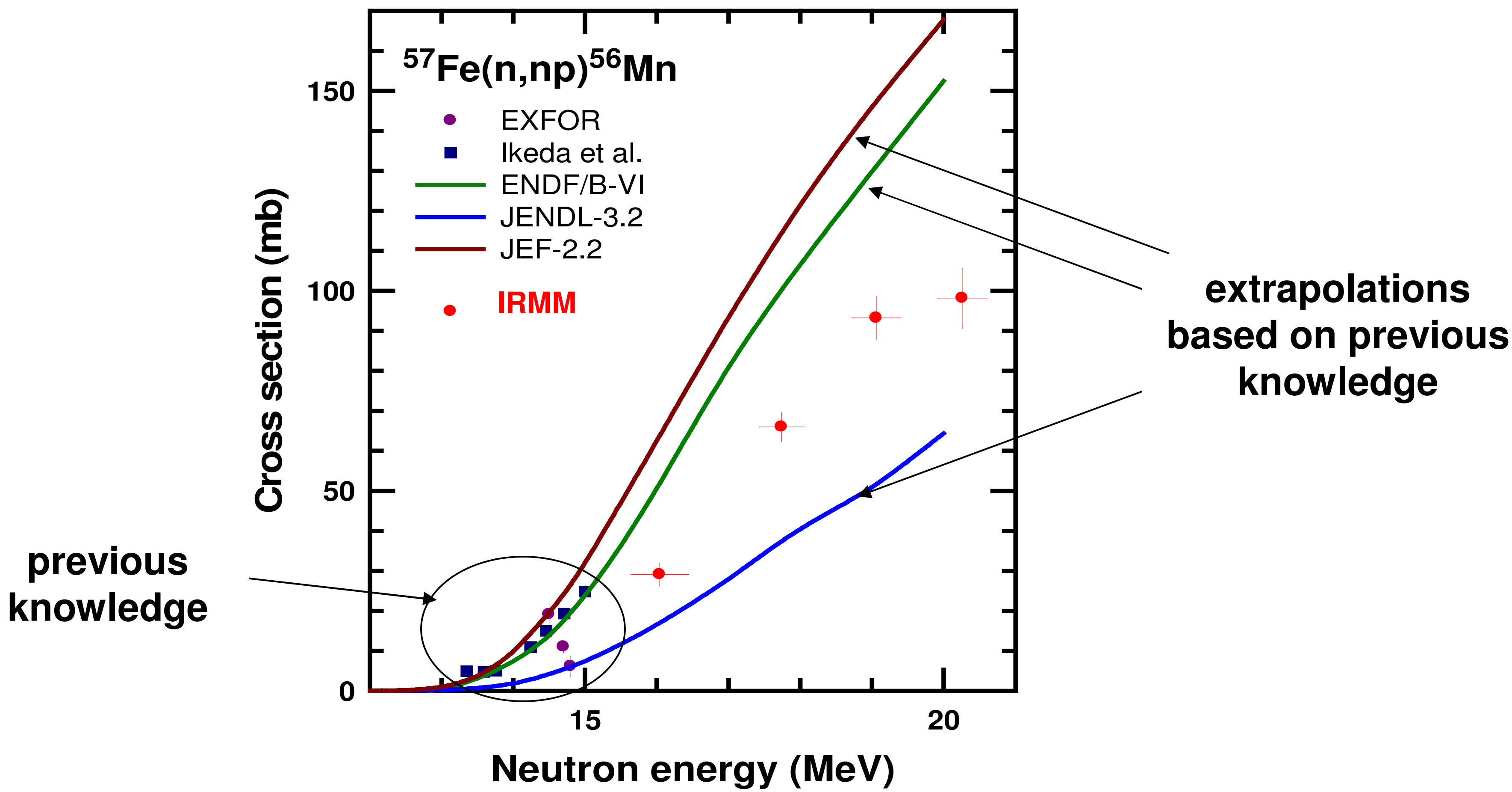
Potential Gen IV Data Needs

- **Data for plutonium and minor actinides**
  - Needed to characterize irradiated fuel, including radiation emission characteristics
  - Needs might include
    - Fission, capture and inelastic scattering cross sections
    - Fission product yields and decay data
    - Energy release per fission
    - Spontaneous fission parameters
    - Radiotoxicity factors
- **Cross section data for non-conventional coolants (e.g., Pb, Bi), structural materials, and fuel matrix materials (e.g., Zr, Mg, Ti)**
- **Gas generation (H and He), and radiation damage data**
- **Evaluated data uncertainties and their correlations (covariances)**
- **Reliable Doppler broadening of specific isotopic cross sections**

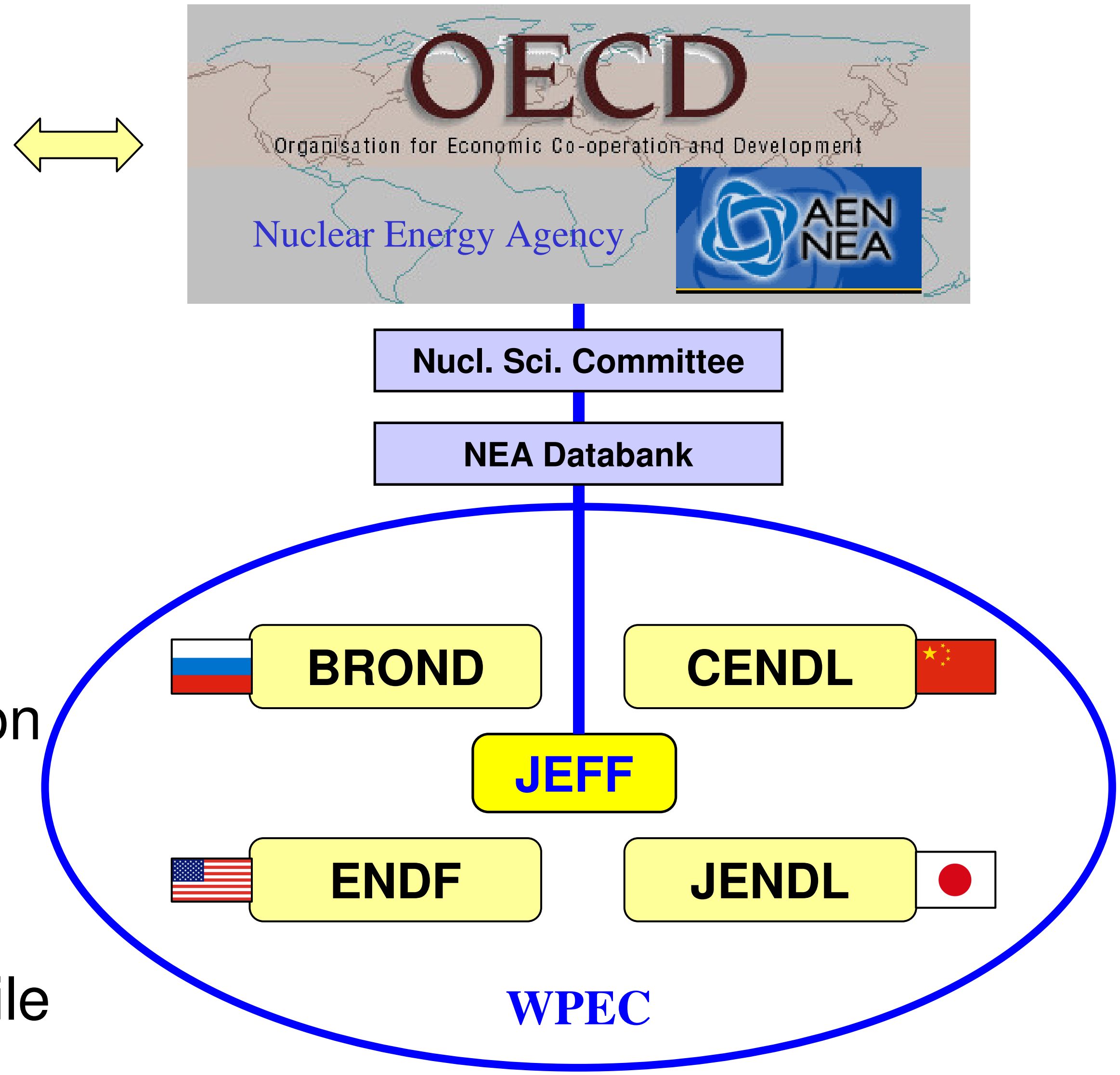
- **More stringent demands in several areas:**
  - unsatisfactory uncertainties and covariance information of available data
  - relevance of different isotopes (e.g. Th-U fuel cycle)
  - reaction channels not yet investigated in enough detail (e.g. (n,2n))

Why neutron data?

There are large uncertainties in data files due to lack of experimental data



The OECD nuclear data network



WPEC:
Working Party for
Evaluation Co-operation

JEFF:
Joint European
Fission + Fusion datafile

JRC Laboratory for Neutron Physics

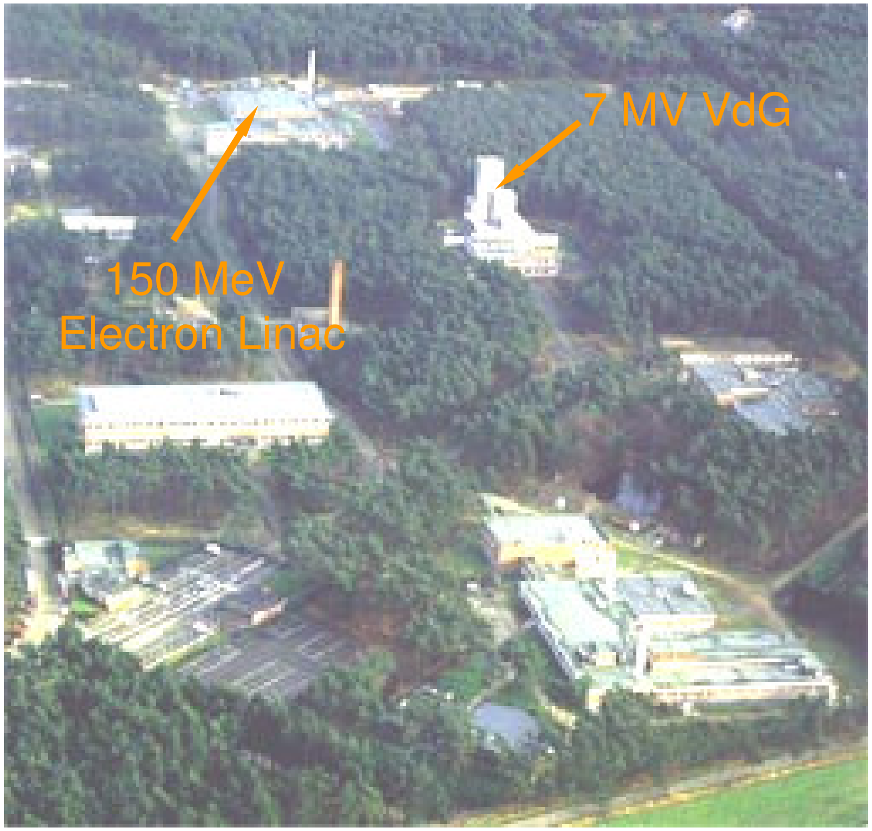
Mission:

provide European safety authorities and industry with neutron data needed for:

- the safety assessment of nuclear installations and the nuclear fuel cycle,
- the feasibility study of waste transmutation facilities and advanced systems

High-resolution neutron reaction data for:

- **Waste Transmutation and Innovative Reactor Concepts**
- **Basic Research in Nuclear Physics and Neutron Data Standards**



exclusively used for neutron production

GELINA
a powerful white neutron source for high-resolution cross section data

High-energy electron accelerator

- 150 MeV electron accelerator (10 ns, 10 A)
- 800 Hz (100 Hz, 40Hz)
- neutron energy range: thermal – 15 MeV
- 4.3 10^{10} neutrons / burst

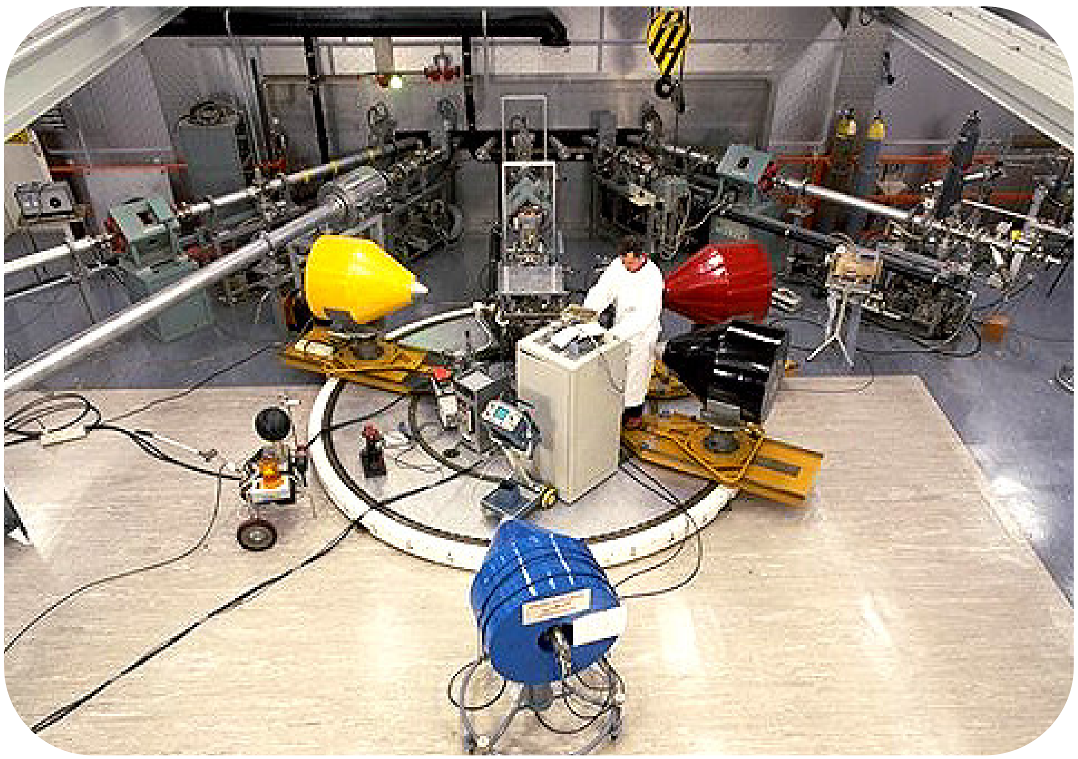
Flight path area

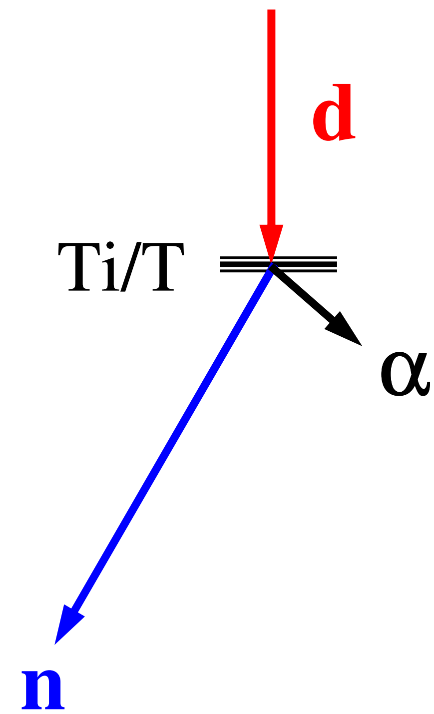
- multi-user facility: 12 different simultaneous experiments
- 24 hours / day basis, 100 h per week

Van de Graaff accelerator

monochromatic neutrons via nuclear reactions

e.g.: $T(d,n)^4He$





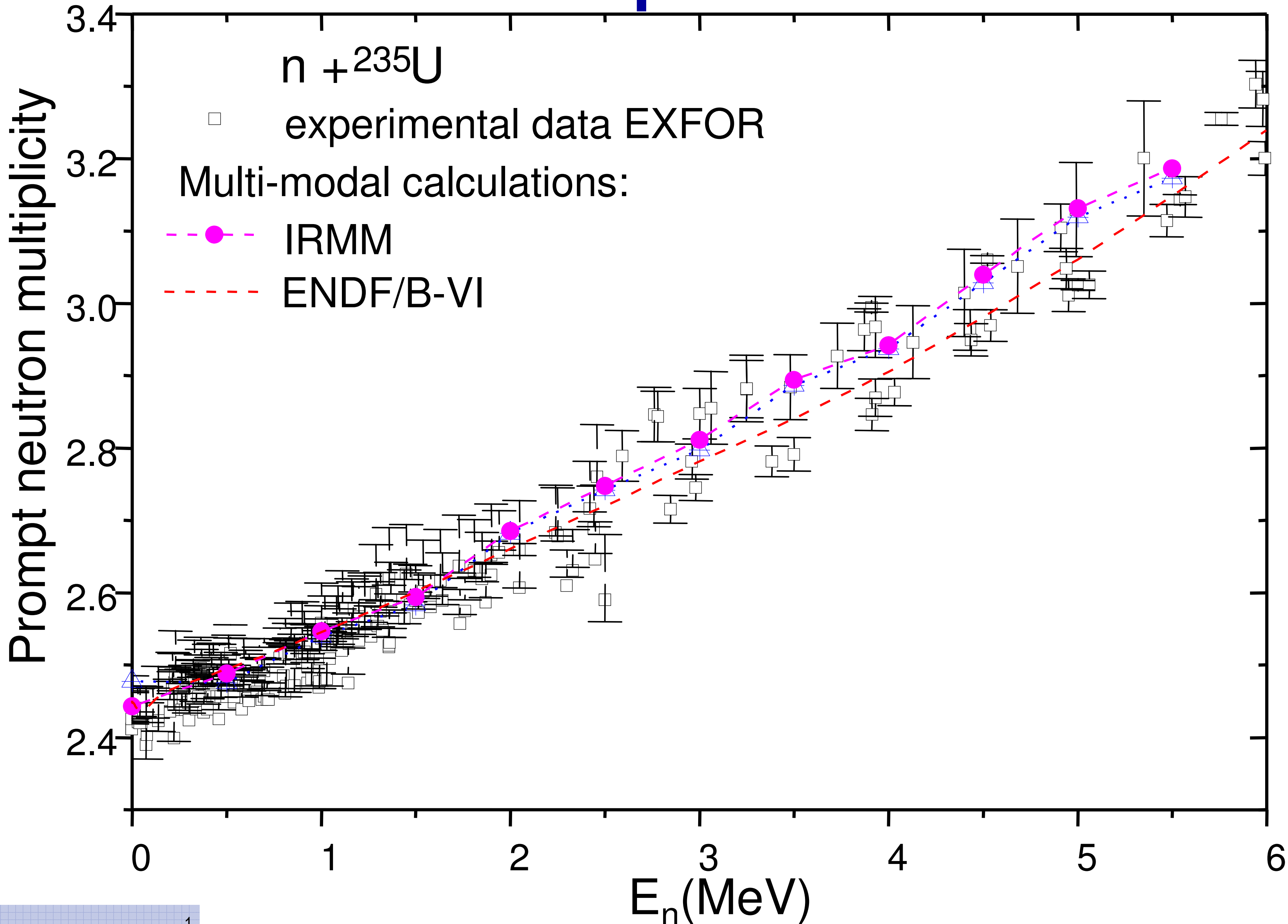
IRMM activities in view of Gen IV

- **High resolution cross section measurements at GELINA and Van de Graaff**
  - support of the Th-U fuel cycle (e.g. capture of ^{232}Th, fission of $^{233,231}Pa$, ^{233}U) for ADS and HTR
  - activation cross section measurements above 14 MeV (n,a), (n,2n), (n,p): survey to verify evaluated nuclear data
  - inelastic cross sections on Pb and Bi for ADS (impact on uncertainty of k_{eff})
  - capture, transmission cross sections on Pb and Bi (ADS target and coolant)

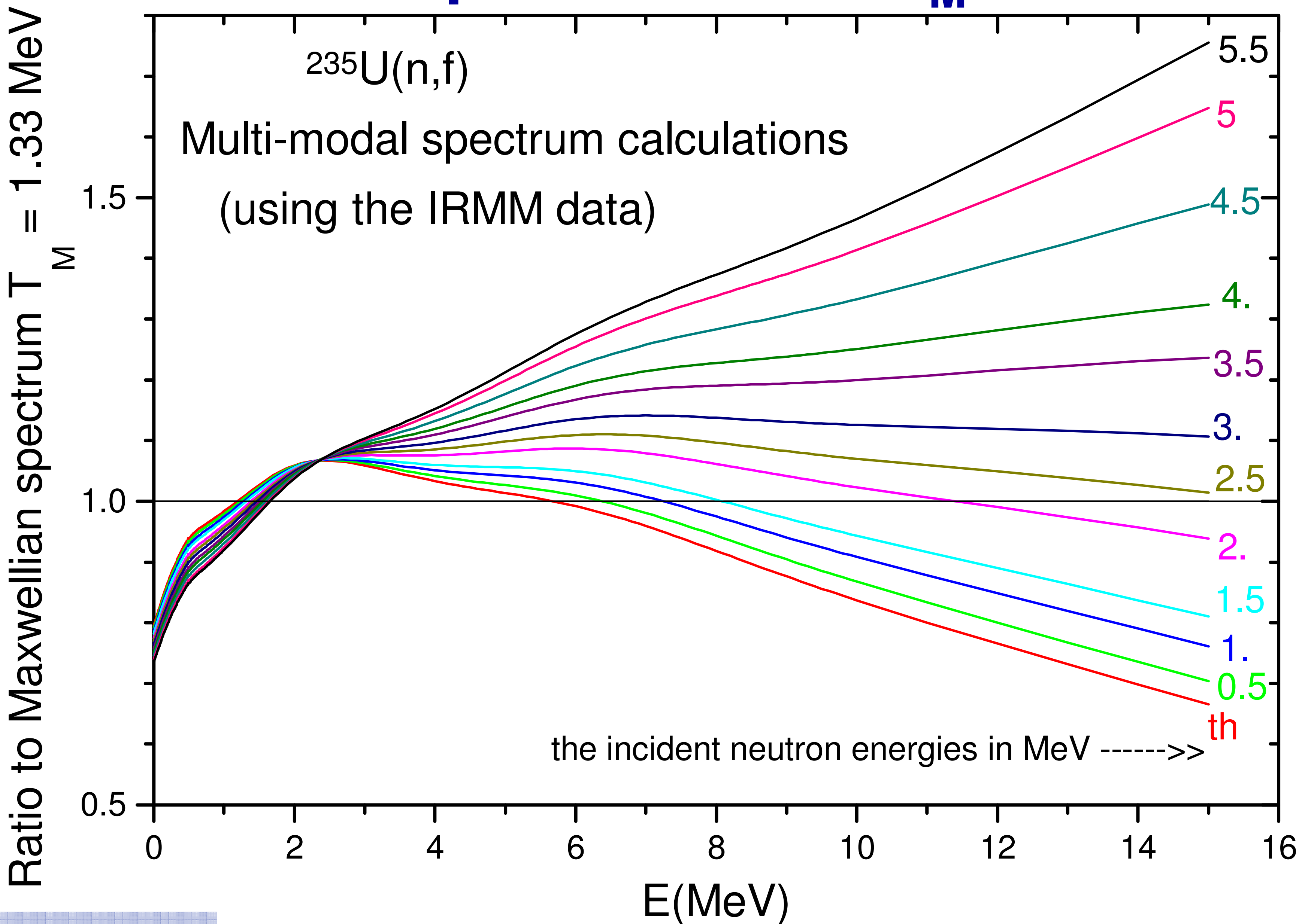
Neutronics

- Neutron spectra and their time evolution
- good knowledge of the fission process
- accurate knowledge of neutron multiplicities and spectra
- fast spectrum fission yields
- improved modelling efforts

Comparison with ENDF/B-VI and experimental data



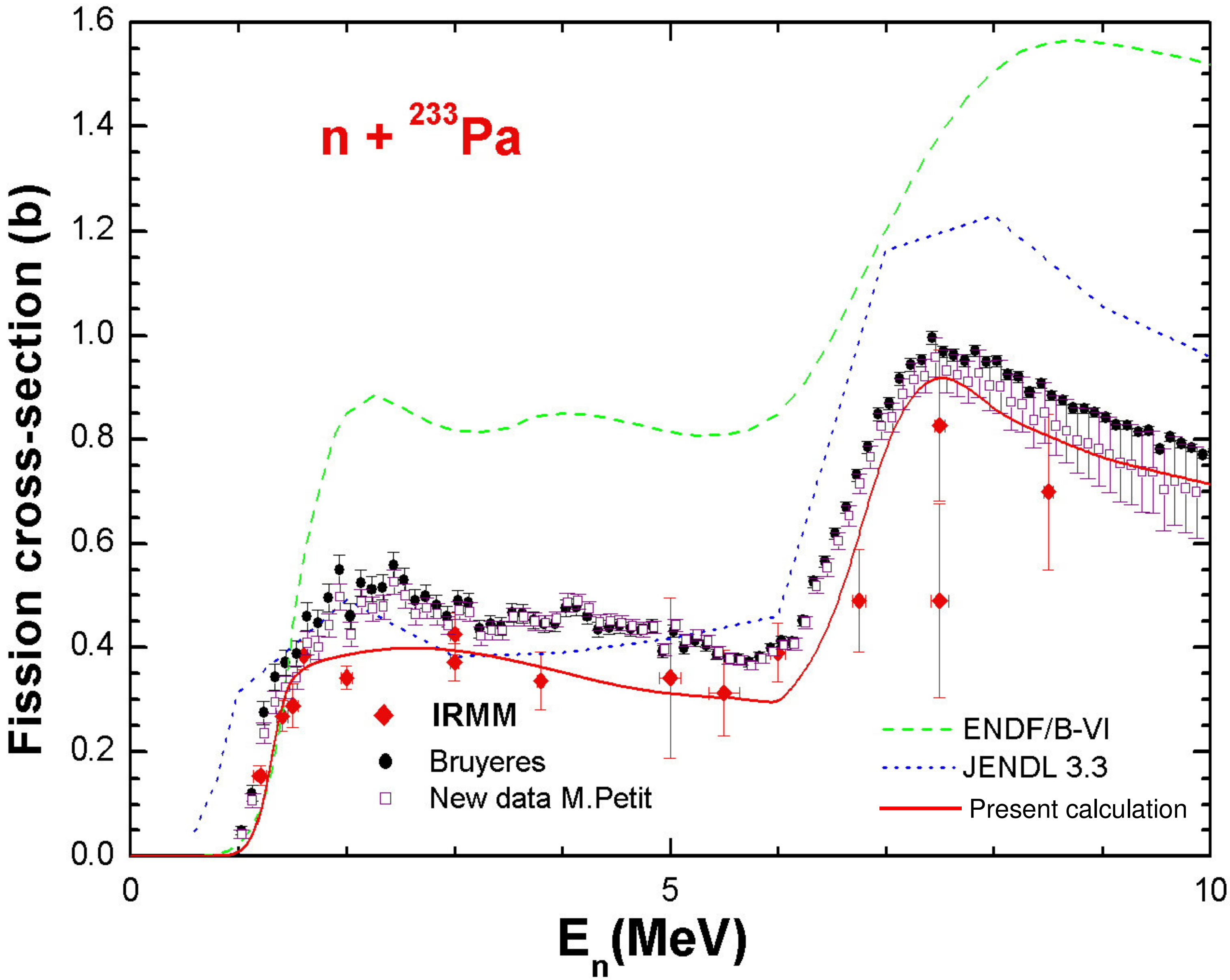
Spectral ratios to a Maxwellian spectrum with T_M = 1.33 MeV



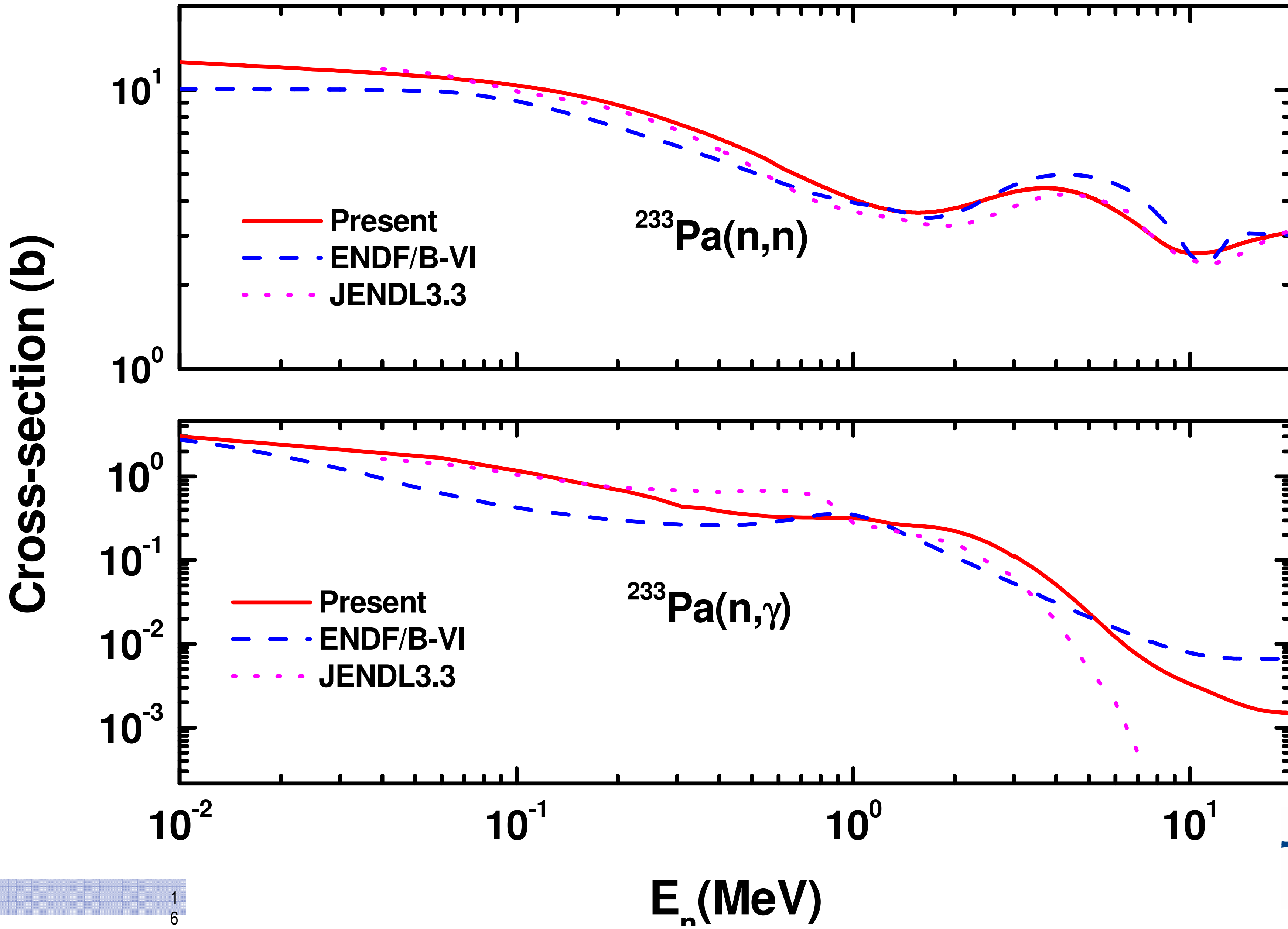
Capture and fission X-sections

- very high burn-up
- increased demand on accuracy of fission and capture x-sections also for major actinides
- modelling efforts

The fast-neutron induced fission cross-section of ^{233}Pa



^{233}Pa elastic and capture cross section



Minor actinides

- Long lived, highly toxic
- major contributor to access heat of waste
- impact on criticality
- accurate assessment of mass inventory in high burnup scenarios
- difficult experimental assessment
- X-section (fission, capture) to assess the transmutation potential

Fission products

- Accurate knowledge of fission yields at higher incident neutron energy
- some FP's are strong neutron poison
- delayed neutron distributions
- influence on neutron spectra
- accumulation of fission products (stable, long lived) -> impact on criticality
- accumulation of uncertainties due to multiple fuel recycling
- need for accurate knowledge of x-sections for lanthanides introduced by pyrochemical separation processes.

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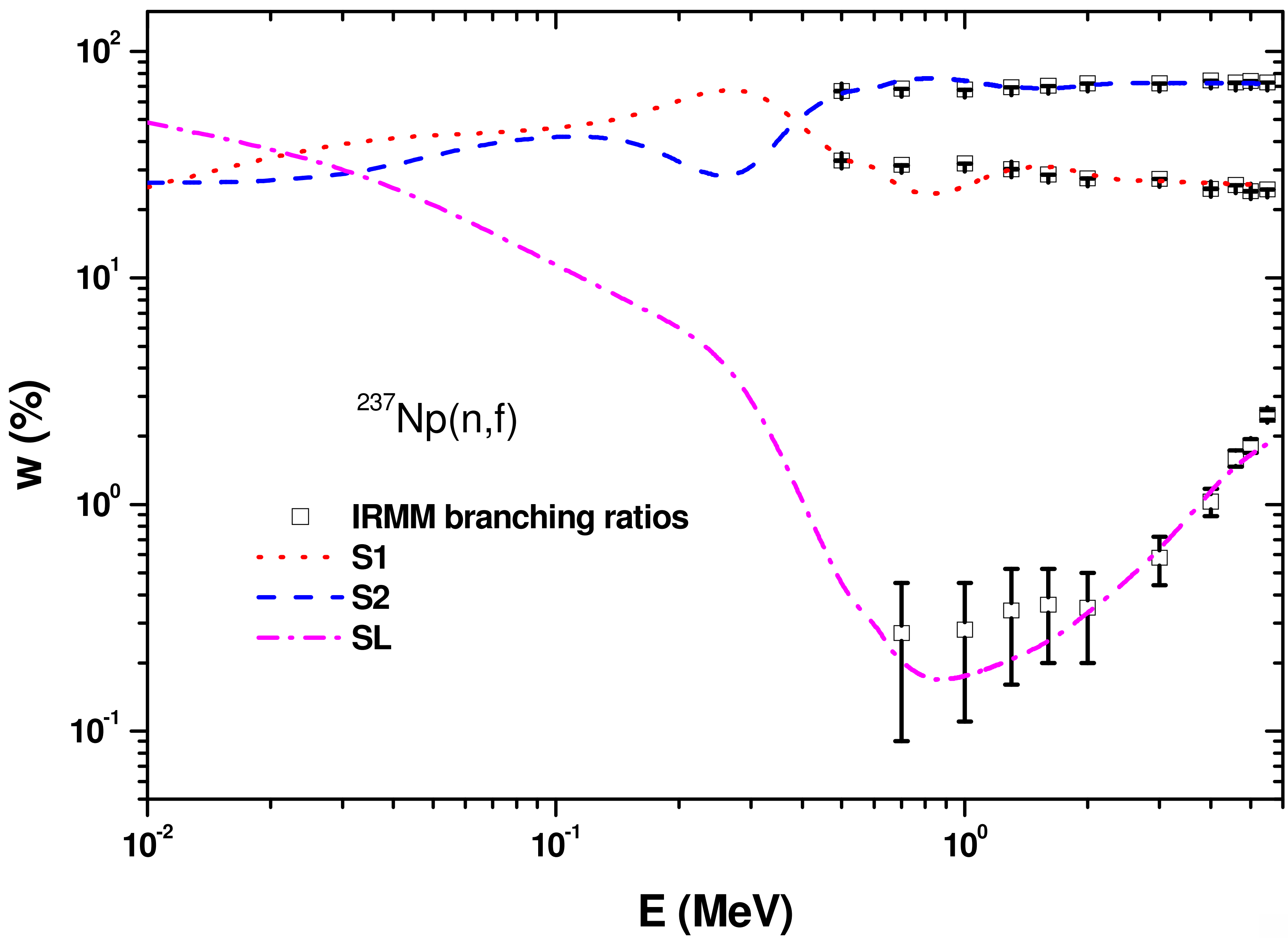
Branching Ratio for ^{237}Np(n,f)



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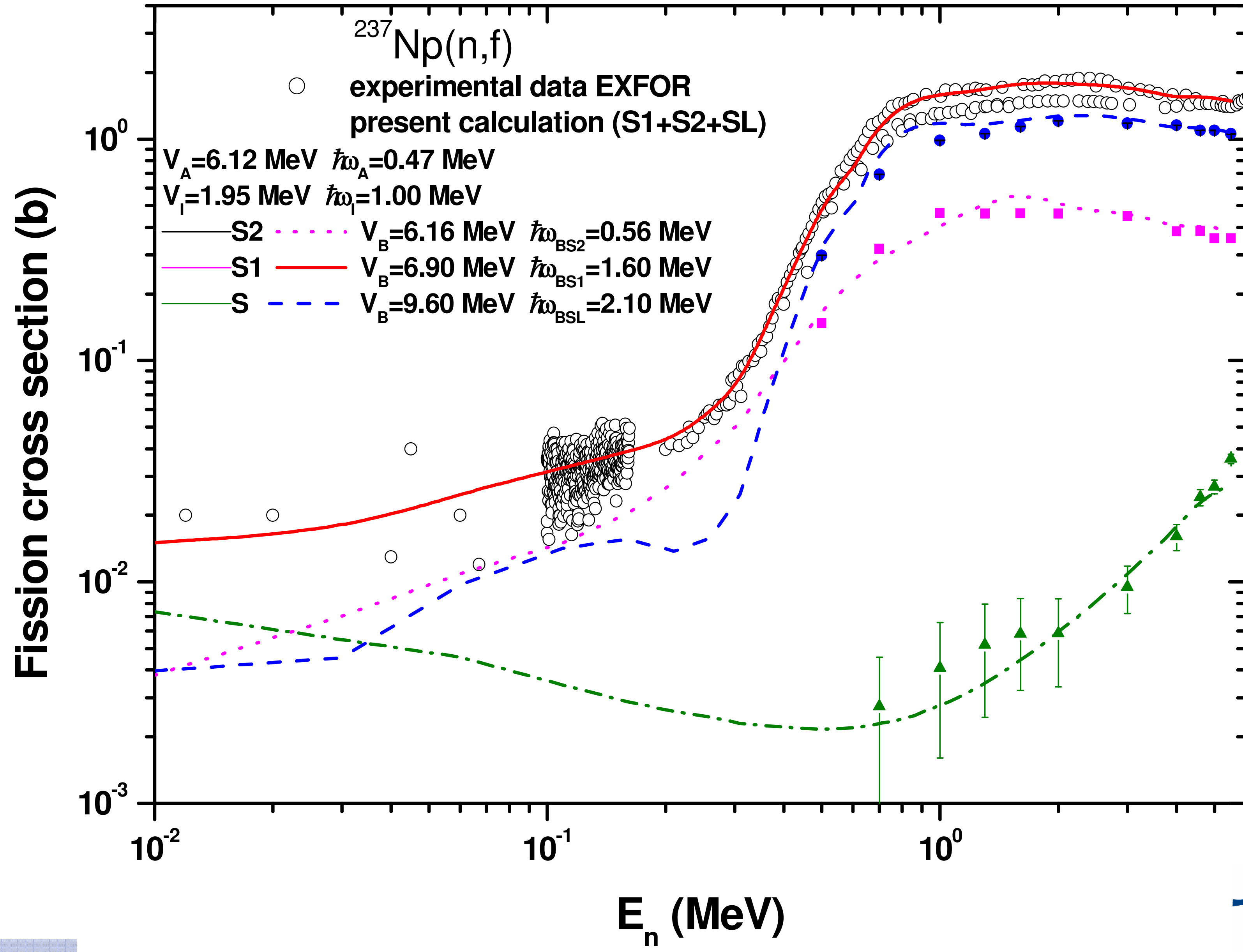
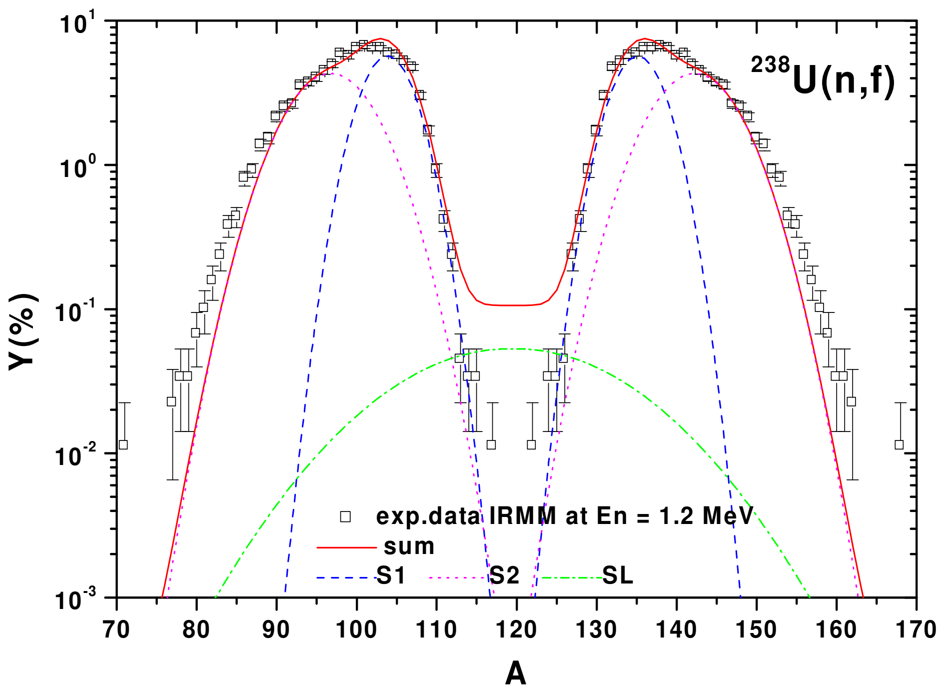
^{237}Np(n,f) fission cross section

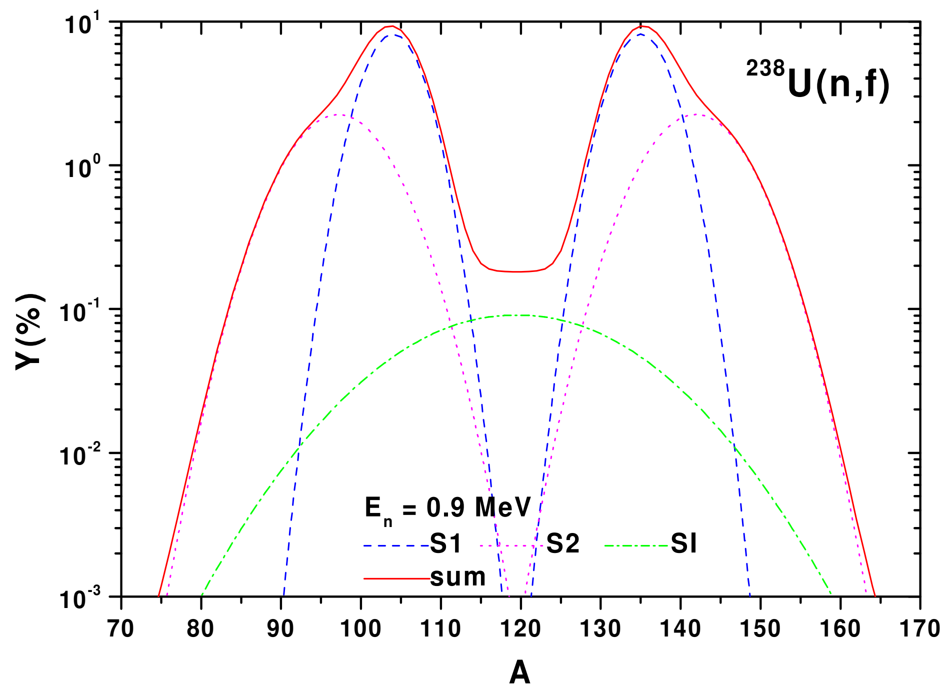


^{238}U(n, f): calculated FF distributions

E_n = 1.2 MeV



E_n = 0.9 MeV



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Exp. Neutron Facilities in Europe

	< 20 MeV	
Athens	INP Demokritos	tandem
Bordeaux	CNRS/ IN2P3/ CENBG	VdG
Braunschweig	PTB	cyclotron, VdG
Bruyères-le-Chatel	CEA/ DAM	VdG
Bucharest	INPE	cyclotron, VdG
Budapest	KFKI	reactor, VdG
Debrecen	ATOMKI	various
Dresden/ Rossendorf	TUD, FZR	(d,t), ELBE
Geel	IRMM	linac, VdG
Geneva	CERN/ n-TOF	spallation source
Grenoble	ILL	reactor
Karlsruhe	FZK	VdG
Orsay	CNRS/ IN2P3/ IPN	tandem
Padova/ Legnaro	INFN	various
Studsvik	NFL, Univ. Uppsala	reactor
	> 20 MeV	
Darmstadt	GSI	RHI: inverse kinematics
Geneva	CERN/ n-TOF	spallation source
Groningen	KVI	cyclotron
Jülich	FZJ/ COSY	p synchrotron
Louvain-la-Neuve	UCL	cyclotron
Uppsala	TSL	cyclotron
Villingen	PSI/ SINQ	spallation source

Other European activities

- N_TOF at CERN
- HINDAS
- EUROTRANS
- HTR-TN
- ….

- Upcoming workshop on nuclear data for GEN IV (date and place to be defined, organized by IRMM)

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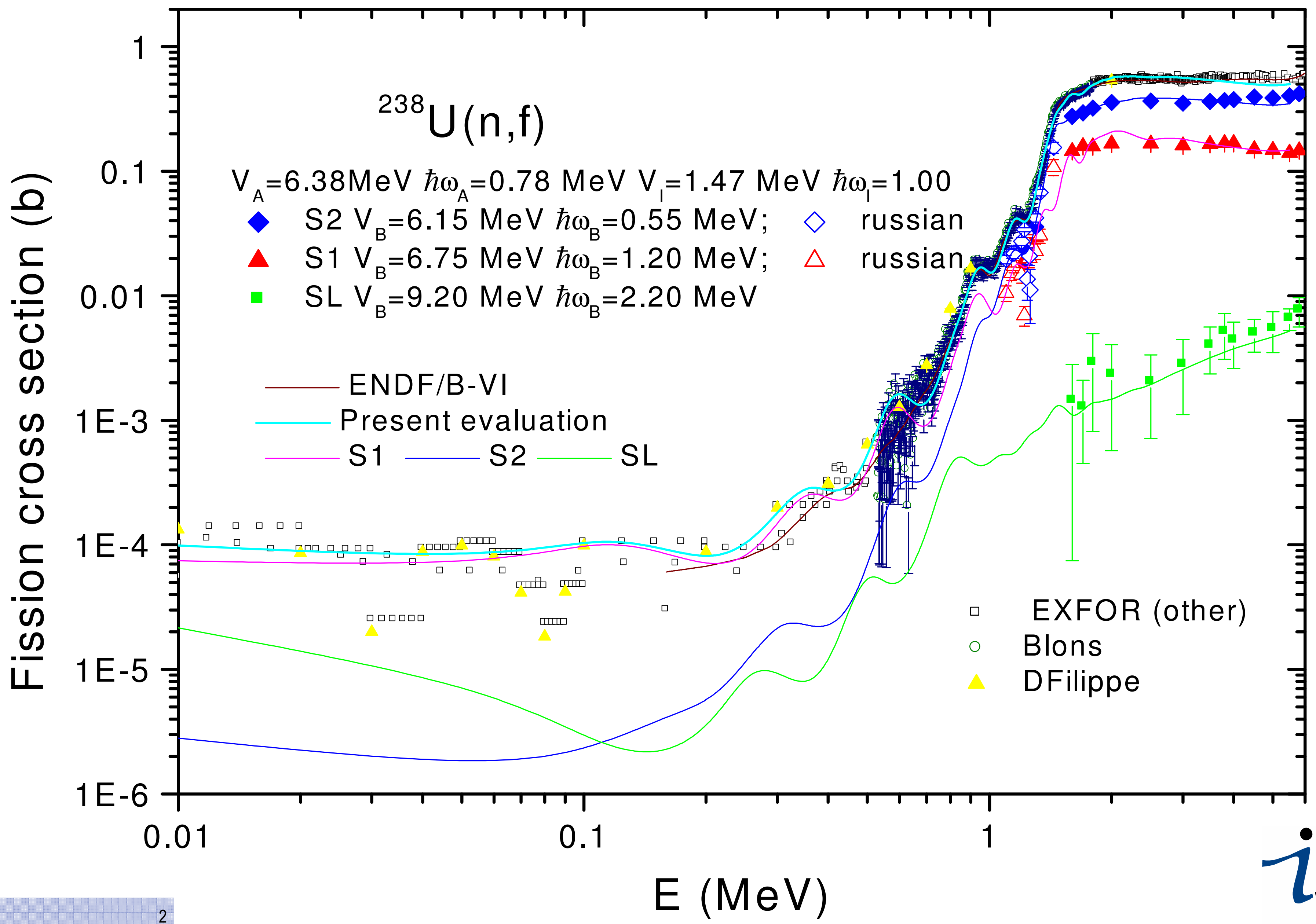
Fission Cross-section for ^{238}U(n,f)



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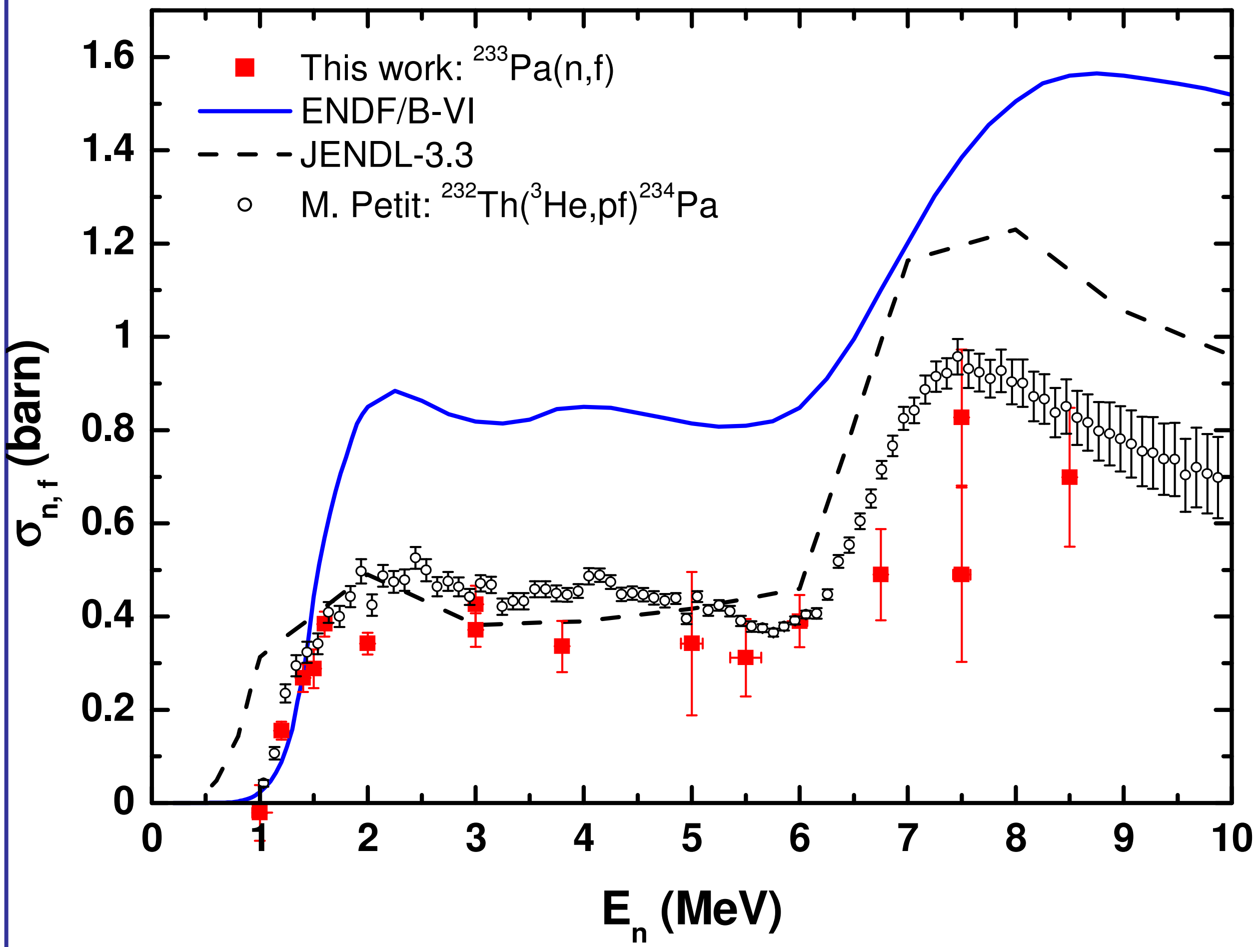
Result: ^{233}Pa(n,f) cross section



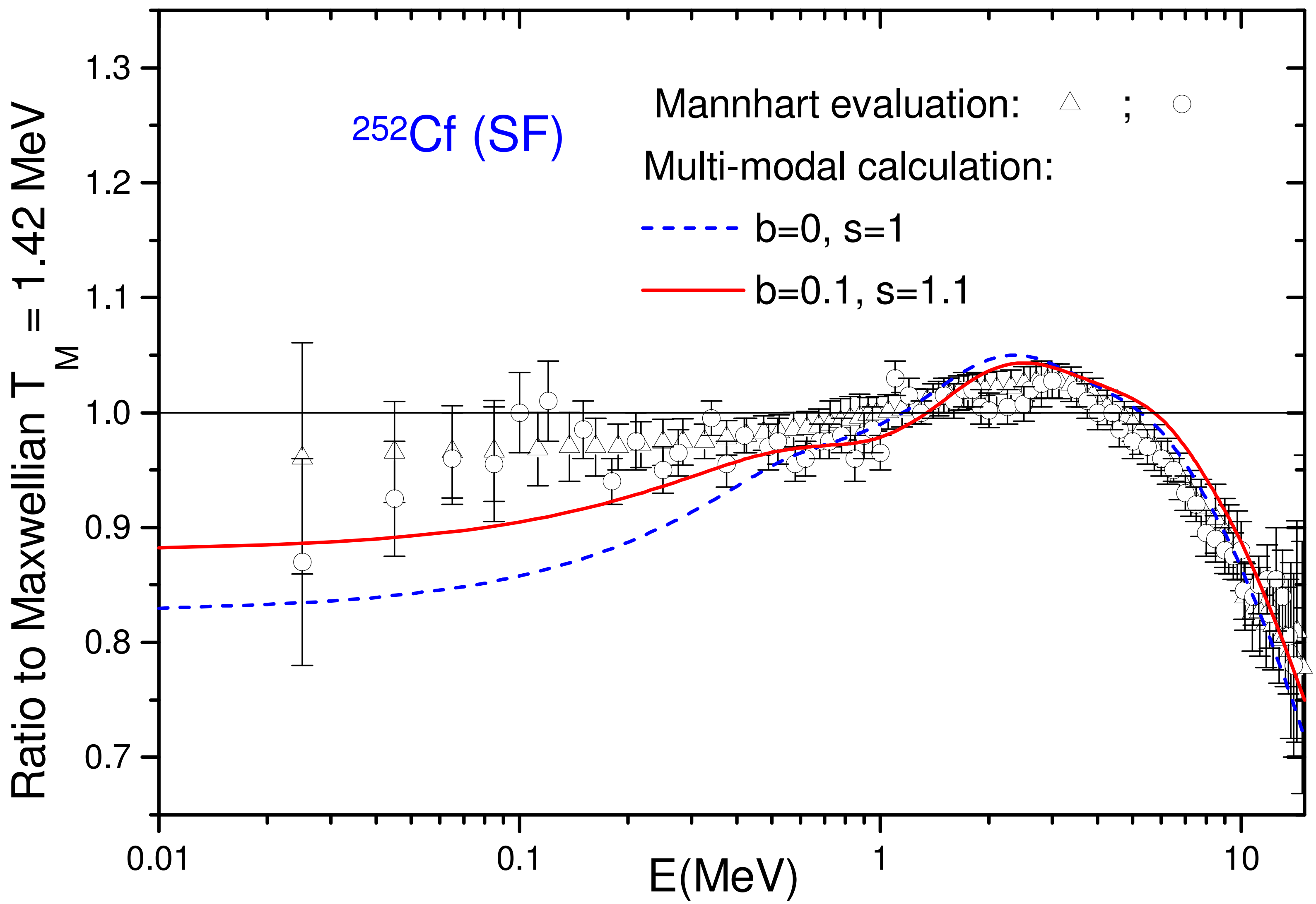
- The present result is lower than all previous evaluations and experiments. Model independent.
- Reasonable agreement with JENDL-3.3 below second-chance fission.
- Cross section values extracted from fission probability data are model dependent. They are in reasonable agreement with the present result, but seem to overestimate the cross section.

$$\sigma_{n,f} = P_f \cdot \sigma_{cn}$$

^{232}Th(^{3}He,pf)^{234}Pa

Model calculation

^{252}Cf(SF) Effects of anisotropy and new P(T) distribution



Depletion and Decay Capabilities

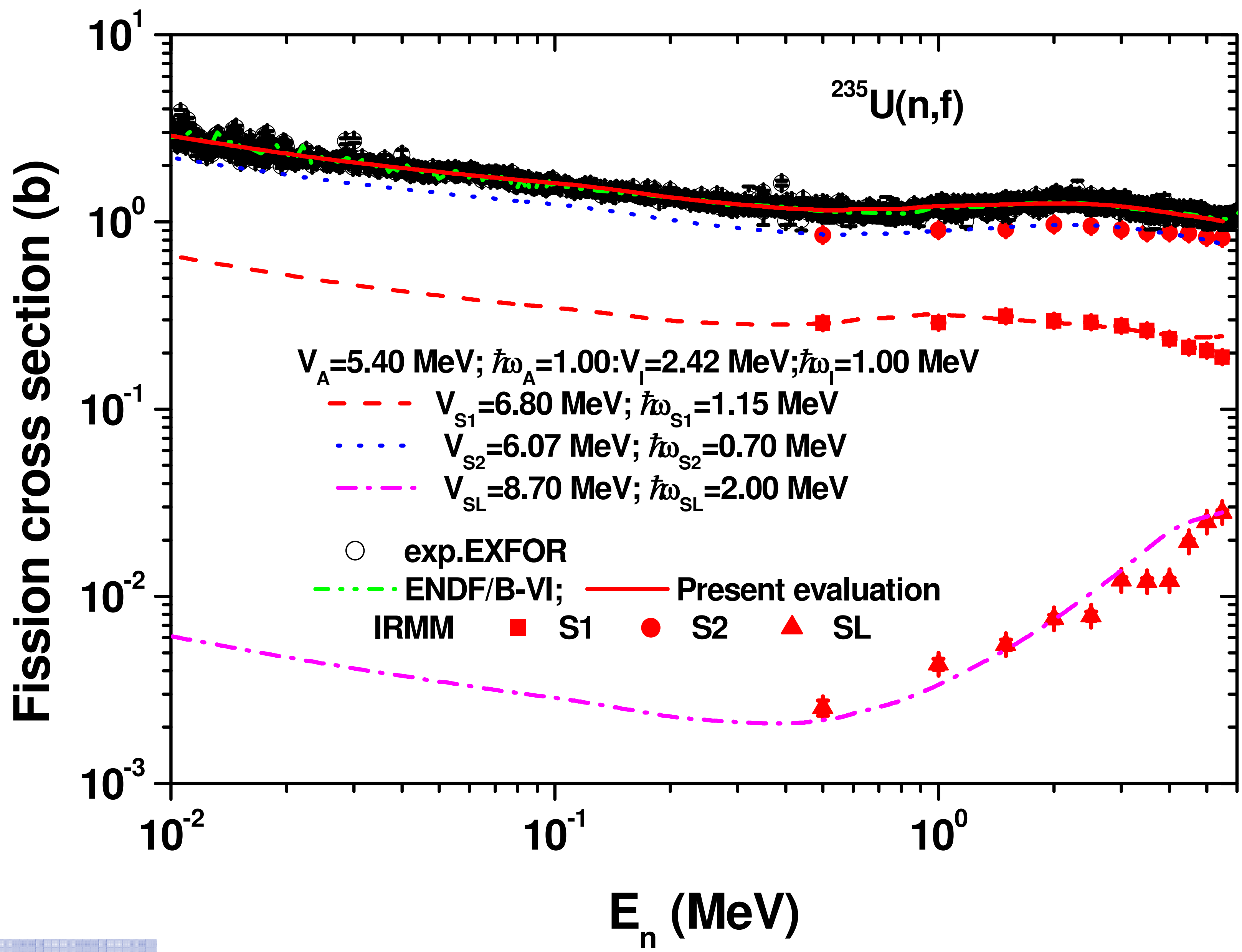
- ORIGEN-S Data Library
  - **Recently expanded and updated activation and fission products from ENDF/B-VI, European Activation File (EAF), and Fusion Library (FENDL)**
  - **Increased nuclides with reaction data from 432 to 617**
  - **Upgrade from ENDF/B-V to /B-VI fission yields in Progress—needed for improved decay heat predictions at short cooling times**
  - **Decay data compiled from ENDF/B-VI and ENSDF Nuclear Data Structure File**
  - **Plans to expand and upgrade photon emission data in FY03**
  - **New ORIGEN-S library to be released in SCALE 5**

Nuclear Data is a Key Element in Gen IV Reactor Analysis

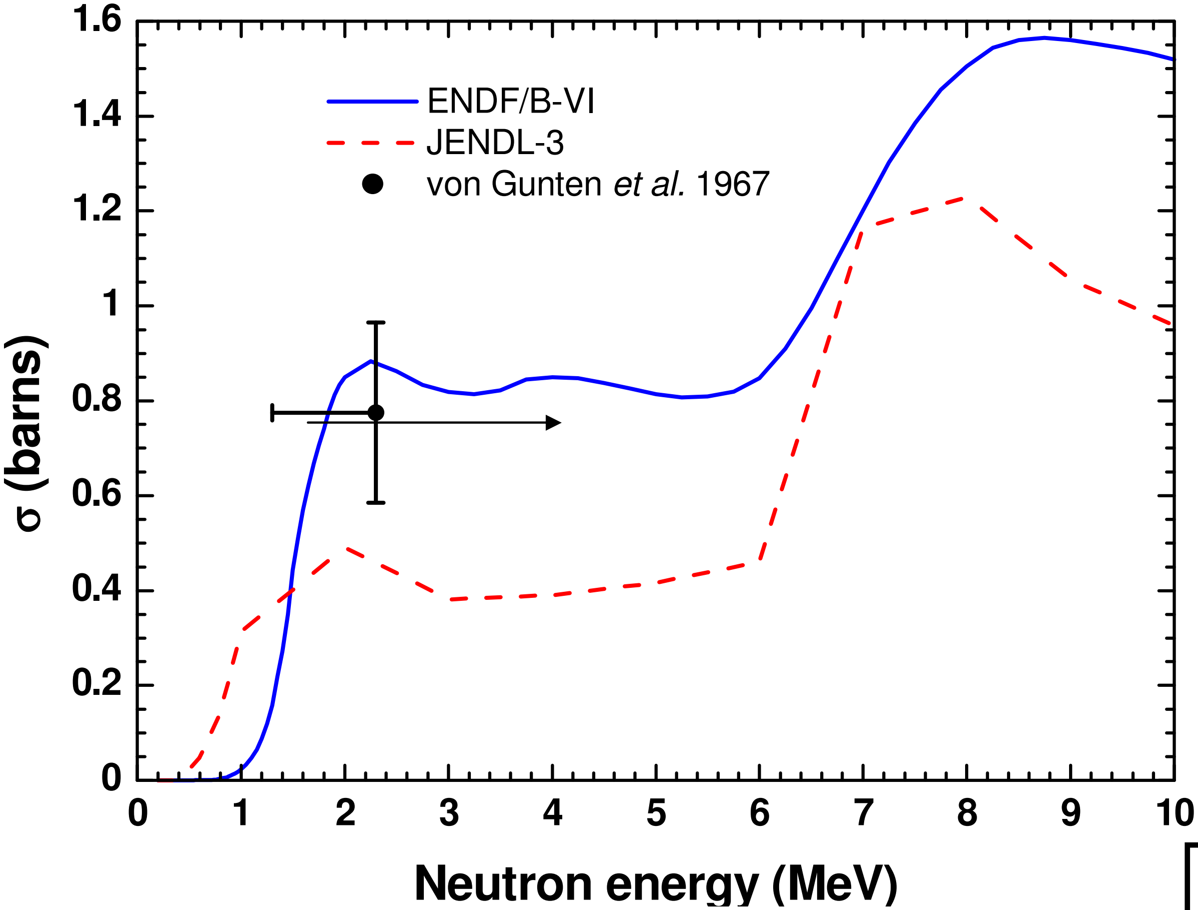
- **Cross sections are key to reactivity effects, and can determine**
  - Reactivity limited burnup
  - Reactivity coefficients
  - Excess reactivity
  - Etc.
- **They also determine discharge isotopics, and thus affect the final waste form and/or the recycle parameters**

- accumulation of fission products (stable, long lived) -> impact on criticality
- accumulation of uncertainties due to multiple fuel recycling
- need for accurate knowledge of x-sections for lanthanides introduced by pyrochemical separation processes.

Calculated fission cross section



Neutron library data



- Only direct measurement dating back to 1967.
- Nuclear reactor used as neutron source (not mono-energetic spectrum!).
- Discrepancy with fission probability measurements.

Differences in the evaluated nuclear data files of up to a factor of 2 for the above threshold fission cross section.

Nuclear Data Needs - GFR

- **Gas cooled Fast Reactor**
  - Reliable actinide cross sections at fission spectrum energies
    - Fission, capture, (n,2n), (n,3n), (n,p), (n,α), etc.
  - Reliable structural and other material cross sections at fission spectrum energies
    - Capture, (n,2n), (n,3n), (n,p), (n,α), etc.
  - Reliable Doppler broadening of specific isotopic cross sections

Nuclear Data Needs - VHTR

- **Very High Temperature Reactor**
  - Reliable graphite scattering kernels at high temperatures (and lower temperatures?)
  - Reliable plutonium cross sections
  - Reliable cross sections for high burnup fuel (i.e., due to buildup of higher actinides)
  - Reliable Doppler broadening of specific isotopic cross sections